A. Cover Sheet *(Attach to front of proposal)*

1. Specify: agricultural project or individual application or
   urban project joint application

2. Proposal title–concise but descriptive: Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices

3. Principal applicant–organization or affiliation: Center for Irrigation Technology (CIT)

4. Contact–name, title: Florence Cassel Sharmasarkar, Ph.D.
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9. Funds requested–dollar amount: $175,010

10. Applicant cost share funds pledged–dollar amount: $106,400

11. Duration–(month/year to month/year): July 2001 to June 2004

12. State Assembly and State districts and Congressional district(s) where the project is to be conducted:

13. Location and geographic boundary of the project:
    Subregions 10 and 14 (West Side San Joaquin Valley)

14. Name and signature of official representing applicant. By signing below, the applicant declares the following:
    – the truthfulness of all representations in the proposal;
    – the individual signing the form is authorized to submit the application on behalf of the applicant;
    – the applicant will comply with contract terms and conditions identified in Section 11 of this PSP.

FLORENCE CASSEL SHARMASARKAR February 14, 2001
(printed name of applicant) (date)

(signature of applicant)

Assessing Spatial and Temporal Variability of Soil Salinity on Farms Implementing Integrated Drainage Management Practices

A Research Proposal submitted to

CALFED WATER USE EFFICIENCY PROGRAM

by

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B. Scope of Work

Relevance and importance

1. Abstract

Many farmlands of the West Side San Joaquin Valley are threatened by excessive salt salinity and inadequate drainage that are affecting crop yields and soil quality. The necessity to reduce salt built-up in soils and improve efficiency of irrigation water use has led to a collaborative effort between the California Department of Water Resources (DWR), Westside Resource Conservation District (RCD), and Westlands Water District (WWD) which called for the implementation of integrated on-farm drainage management (IFDM) practices in the region. Such practices are expected to conserve irrigation water by reducing drainage water outflow within the farm boundaries. Knowledge of soil salinity distribution on a farm level will be critical to evaluating the effects of the new practice and maintaining crop productivity. This research proposes to use electromagnetic induction (EM) surveys and geostatistical analyses as reconnaissance tools to assess spatial and temporal variability of soil salinity following implementation of IFDM practices by DWR, RCD, and WWD in several farms of sub-regions 10 and 14. The project will be conducted over three years and will partially address CALFED Quantifiable Objective 106 by evaluating the effectiveness of IFDM on reducing soil salinity and improving efficiency of water use. The study will provide vital data for the success of the IFDM approach program both as a baseline for the initial implementation phase and then as a decision-making tool for management of the drainage system and selection of crop rotations.

2. Statement of the problem

Salinization is a critical and persistent problem in many irrigated agricultural lands of California because of shallow saline water table and inadequate drainage that prevent leaching of soluble salts. For example, in 1997 combined areas of shallow groundwater (0 - 5ft. from the soil surface) in Grasslands, Westlands, Tulare, and Kern sub-areas reached 743,000 acres (San Joaquin Valley Drainage Implementation Program, 1998). If this drainage impacted area should reach 1 million acres, that would represent about 40% of the irrigable farmland in the Westside and southern San Joaquin Valley (San Joaquin Valley Drainage Program, 1999). Excessive soil salinity can affect crop productivity, soil structure, water quality, and can accelerate soil erosion. These salinity related impacts eventually result in land degradation.

In California, approximately 4.5 million acres of irrigated farmland are estimated to be affected by saline soils or saline irrigation water (Letey, 2000). Prior to 1984, just over 2.9 of California's 10.1 million irrigated acres were salt-affected, i.e. the electrical conductivity of saturated paste extract (ECe) of these soils was greater than 4 dS/m (Backlund and Hoppes, 1984). Salinization is particularly a threat in the West Side San Joaquin Valley (SJV), where the NET salt inflow into this region every day during the irrigation season is approximately 1.3 million metric tons (1.46 million U.S. tons) which is equivalent to about 40 railroad cars of salt (San Joaquin Valley Drainage Implementation Program, 1998).

To reduce salinization in the region, integrated on-farm drainage management (IFDM) practices involving sequential use of drainage water and harvesting of drainage salts are being implemented in a collaborative effort between the California Department of Water Resources (DWR), Westside Resource Conservation District (RCD), and Westlands Water District (WWD). Approximately twenty farms are expected to enroll in the program. Assessment of the spatial and temporal variability of soil salinity will be essential to evaluating the benefits of the IFDM practices. Therefore, we propose to monitor and assess salinity changes in the soil profiles over time by conducting regular salinity surveys on the farms implementing IFDM. The study will provide vital data for the successfulness of the IFDM approach program both as a baseline for the initial implementation phase and then as a decision-making tool for management of drainage system and selection of crop rotations.

3. Nature, scope, and objectives

Soil salinity is difficult to quantify because of rapid changes over space and time. Traditional measurement methods, such as four-electrode probes and soil sampling, require extensive data collection and laboratory analyses that are very slow, labor-intensive, and expensive (Davis et al., 1999; McKenzie et al., 1997). The electromagnetic (EM) induction technique has become a very useful and cost-effective tool to monitor and diagnose soil salinity over large areas, because it allows for rapid, aboveground measurements with non-invasive sampling (Ceuppens et al., 1997; Hendrickx et al., 1992; Lesch et al., 1992). Additionally, EM sensors generally provide better and faster estimates of soil salinity than direct methods (Sudduth et al., 1999; McKenzie et al., 1997). The EM instrument's transmitter coil induces an electromagnetic field in the ground, which in turn create a secondary magnetic field that is measured by the receiver coil (McNeill, 1980). By producing this electromagnetic field, the EM meter is able to measure the depth-weighted apparent electrical conductivity (EC_a) in a volume of soil below both coils (Rhoades and Corwin, 1990; Slavish, 1990). Since solid soil particles and rock material have very low EC (McNeill, 1980), the instrument response is primarily influenced by the electrolyte concentration of the soil water, i.e., salinity.

Geostatistical analyses of the EM data are also necessary to characterize the spatial distribution of soil salinity on the farms and determine the relative extent of salinity problems in the region. Geostatistical methods have been extensively used to describe the spatial distribution of soil properties in agriculture (Cambardella et al., 1994; Meirvenne and Hofman, 1989). Knowledge of salinity variability and characterization of spatial distribution in the fields are important for statistically evaluating areas of low and high salt contents, and providing management recommendations. Geostatistical methods are also important to determine the spatial dependency between EM measurements which is necessary for recommending optimum sampling scheme.

The overall goal of the proposed research is to assess soil salinity patterns and time-dependent changes on farms implementing drainage management practices in subregions 10 and 14 using EM induction surveys and geostatistical analyses. Initial baseline appraisal and periodic monitoring of the evolving salinity conditions will be essential to determine the impacts of IFDM practices on reducing soil salinity and maintaining crop productivity, and to provide future irrigation drainage and cropping management strategies.

The specific objectives of the proposed research are:

1. To annually monitor and map soil salinity on farms involved in the IFDM program using an EM induction technique,
2. To investigate relationships between soil salinity measurements and existing soil data, and
3. To characterize the spatial distribution of soil salinity using geostatistical methods.

Technical/Scientific Merit, Feasibility, Monitoring, and Assessment

4. Methods, procedures, and facilities

We anticipate that approximately 20 farms will participate in the IFDM program, with each farm covering an average area of 1000 acres. The farms will be located in the subregions 10 and 14 of the West Side San Joaquin Valley. The methodology for the objectives outlined in section B.3. is detailed below.

· *Objective 1. Annually monitor and map soil salinity on farms involved in the IFDM program using EM induction technique*

a. Equipment

To rapidly collect EC data on these vast farmlands, we will design a Mobilized Soil Conductivity Assessment (MSCA) system comprising of four basic components: (1) an electromagnetic (EM) induction sensor, (2) a global positioning system (GPS) receiver, (3) a computer, and (4) an all-terrain vehicle (ATV) on which the 3 previous components will be mounted.

i. EM induction sensor

A Geonics dual-dipole EM-38 instrument (DDEM-38; Geonics Limited, Ontario, Canada) will be used to measure soil electrical conductivity (EC_a) down to a depth of about 6 ft. The DDEM-38 meter comprises of two integrated EM-38 units with coils oriented in both the horizontal and vertical positions to provide synchronized measurements over observation depths of 0-3 ft and 3-6 ft, respectively. This sensor will be most suited to measure salinity at depths corresponding to the approximate rooting length of shallow- and deep-rooted crops.

ii. GPS receiver

A GPS is a satellite-based, three-dimensional, radio-navigation system established by the U.S. Department of Defense (Parkinson and Spilker, 1996) that broadcast signals to a GPS receiver capable of determining any geographical position. In this study, a Trimble AgGPS® 132 receiver (Trimble Navigation Limited, 1999) will be used in conjunction with the EM sensor to provide the coordinates of each measurement point. The GPS data will then be differentially corrected by post-processing to obtain absolute position with an accuracy of 3-6 ft.

iii. Computer

Two serial RS232 digital interfaces will connect the EM sensor and GPS receiver to an on-board laptop computer that will instantaneously record the EM readings along with their GPS location. An ESAP-95 software recently developed by Lesch and Rhoades (1999) and a Sandia software (Sandia National Laboratories, NM) will be used to analyze and record the EC data, respectively.

iv. ATV

The vehicle used will be a SpraCoupe with no external spray components. The EM sensor will be placed in a carrier-sledge attached at the rear of the ATV. The carrier-sledge will be made of plastic to avoid any EM reading interference due to metallic objects. A distance of approximately 10 ft will be maintained between the carrier-sledge and ATV to eliminate the effects of engine noise on the sensor performance.

b. Data collection

i. EM measurements

EC_a and GPS data will be collected along transects (field rows) 75 to 125 ft apart depending on row spacing, and recorded on a 2 second interval which will correspond to measurements every 15 ft at a travel speed of about 5 mph. This procedure will result in a data density of about 24 to 39 points per ac. Both horizontal $EC_{a(H)}$ and vertical $EC_{a(V)}$ readings will be recorded to obtain effective measurement depths of 3 ft and 6 ft, respectively. The simultaneous measurements of different depths will allow the distribution of soil EC with depth to be inferred. Initial baseline measurements will start in fall 2001 before the implementation of IFDM. Then, measurements will be taken once a year at the same period for the two consecutive years (fall 2002 and 2003).

ii. Ground truthing soil sampling

Based on the EC_a measurements obtained with the EM-38, the first program of the ESAP-95 software will perform statistical analyses of the data and generate an optimal soil sampling plan that will be spatially representative of the entire survey area. Ground truthing soil sampling will then be conducted on the same day at each of the sites selected by the program. The geographical positioning of those sites will be easily located with the GPS and the navigational screen of the Sandia program. Soil samples will be collected in 2 ft increments to a depth of 6 ft, using 2-in diameter coring tubes. These coring tubes are attachments for a hydraulically driven soil augering Giddings® rig. Electrical conductivity will be determined on the saturated soil extract (EC_s), following recommendations by Diaz and Herrero (1992) and using standard analytical methods (Rhoades, 1996).

c. Data analyses

Calibration of the EC_a data will be performed using the second program of ESAP-95 software. Based on the EC_s soil sample analyses as well as the $EC_{a(H)}$ and $EC_{a(V)}$ measurements, the program will determine a regression model (stochastic calibration equation) which will directly convert the EC_a data into estimated soil salinity values (EC_e) for the entire survey area. EC_e values will be provided for the four depths measured during ground truthing (i.e., 0, 2, 4, and 6 ft). Then, contour maps showing the salinity distribution on all farms will be generated for each soil profile depth using the Surfer software (Golden Software, 1999) and ArcView GIS (Environmental System Research Institute, 1996). One-dimensional graphs showing differences in salinity levels with depth along transects will also be produced.

· *Objective 2. Investigate relationships between soil salinity measurements and existing soil data*

Firstly, soil maps on existing soil data will be obtain for areas where farms have been selected for the IFDM practice. The Agricultural Technology Information Network (ATI-NET) at the California Agricultural Technology Institute (CATI) will assist in compiling this soils database as well as providing CIT with the geo-referenced digital map data and computerized attribute data. ATI-NET, in turn, will work with the National Resources Conservation Service (NRCS) to compile the information on soil pH, soil texture, and soil fertility by using the State Soil Geographic (STATSGO) database for California.

Soil pH and average clay content of the surface horizon will be calculated for each map unit from the weighted average of all soil series indicated within the map unit, using methods described in detail by Davidson and Lefebrve (1993). These soil map units will then be assigned to aggregated texture classes following the procedure outlined by the Food and Agricultural Organization (FAO, 1971). Soils will be grouped in one of four texture classes based on their clay content as follows:

(1) Class 1: 0-5% clay;
(2) Class 2: 5-15% clay;
(3) Class 3: 15-30% clay; and,
(4) Class 4: >30% clay.

The grouping is based on clay content because the most common texture class in California is the coarse-medium 5-15% clay, which covers 30% of the state, followed by the coarse (0-5% clay) and medium (15-30% clay) texture classes which each account for about 22% of the state's soil (C.F. Krauter, Soil and Irrigation Professor, Fresno State University, personal communication). STATSGO data at the level of Soil Order in the U.S. classification will be used to define general fertility classes as low, medium or high fertility (Birkeland, 1974).

Secondly, ATI-NET will layer the salinity data collected from objective 1 of the study over the compiled soil data maps in order to depict any relationships between the soil parameters and the salinity measurements.

- <u>*Objective 3. Determine the spatial variability of EC using geostatistical analyses*</u>

Geostatistical analyses of soil salinity data will be conducted using the Geostatistical Environmental Assessment Software, GEO-EAS and GSLIB library (Englund and Sparks, 1988; Deutsch and Journel, 1992). The spatial structure of the variable will be determined through fitted variograms in a two-step procedure: (i) computation of experimental variograms, and (ii) fitting them to theoretical models validated by the cross-validation technique. Model fitting for the variograms will be selected based on sample variograms and statistical results obtained from cross-validation (Vieira et al., 1983). Such validation is a technique in which the known data points are evaluated using the fitted model. Model variograms will help determining the distance up to which soil salinity measurements are autocorrelated (i.e., the distance between which salinity data are likely to be similar). Such findings will be valuable to determine if salinity levels are statistically different among fields. Knowledge of spatial autocorrelation will also be important to design optimum sampling scheme.

Estimation of the measured variable at unsampled locations will be accomplished using kriging. Kriging is a linear unbiased estimation method that minimizes the variance of error, and provides estimates at unsampled points based on the surrounding data collected at precise sample locations (Isaaks and Srivastava, 1989). The intrinsic hypothesis is that the variogram depends on the separation distance between samples and not on the sampling location. Kriging will thus provide soil salinity information at any point throughout the all farms.

Geostatistical analyses will also help in determining any correlation between the EC measurements and the soil parameters data obtained from Objective 2 (soil pH, average clay content). Then, an alternative technique, cokriging, will be used if the variables are cross-correlated. Cokriging utilizes both spatial dependence and inter-variable correlation, and is very useful when the number of samples for one variable is less then the other. Thus, we can characterize the spatial variability and distribution of soil pH and average clay content very accurately using soil salinity data collected on an extensive scale. Spatial patterns obtained from kriging and cokriging will be presented as contour maps using SURFER (Golden Software, 1999).

<u>5. Schedule</u>

The project will be conducted over a three-year period, from July 1st 2001 to June 30th 2004. The major milestones to be accomplished each year are outlined below.

Year 1 (July 1st 2001 to June 30th 2002):

- Assessment of irrigation and cropping practices followed by all growers enrolling in the IFDM program,
- Initial EM measurements conducted before the start of IFDM implementation to obtain a baseline assessment of soil salinity on all farms,

- Ground-truthing soil sampling, calibration, and soil salinity mapping,
- Geo-referencing of initial EM measurements with existing soil data,
- Geostatistical analyses based on initial EM data,
- Presentation of soil salinity maps and findings to growers, DWR, RCD, and WWD,
- Recommendations on initial IFDM design and crop rotations based on soil salinity distribution,
- Preparation of first year report, extension newsletter.

Year 2 (July 1st 2002 to June 30th 2003):
- Second set of EM measurements after implementation of IFDM
- Ground-truthing soil sampling, calibration, and soil salinity mapping,
- Geo-referencing of 2nd year EM measurements with existing soil data,
- Geostatistical analyses based on 2nd year EM data,
- Recommendations on crop rotations and IFDM operations,
- Presentation of soil salinity maps and findings to growers, DWR, RCD, WWD, cooperators, and the scientific community through seminar, workshop, professional meetings.
- Preparation of second year report and bulletin.

Year 3 (July 1st 2003 to June 30th 2004):
- Third set of EM measurements after implementation of IFDM
- Ground-truthing soil sampling, calibration, and soil salinity mapping,
- Geo-referencing of 3rd year EM measurements with existing soil data,
- Geostatistical analyses based on 3rd year EM data,
- Preparation of final report and peer-reviewed journal article,
- Presentation of three-year results to growers, DWR, RCD, WWD, cooperators, and the scientific community through seminar, workshop, professional meeting.
- Evaluation of IFDM effectiveness in reducing soil salinity and improving drainage water use efficiency; assessment of crop productivity,
- Recommendations for future actions and studies.

<u>6. Monitoring and assessment</u>

Soil salinity surveys, geo-referencing, and geostatistical analyses will be conducted over a three-year period. Initial EM measurements will be performed from October 2001 on all farms enrolled in the IFDM program at the time. Two other EM measurements will be taken during on-going IFDM in Fall 2002 and 2003 to monitor salinity response to the new practice. Following each EM survey, salinity maps will be produced, and geo-referencing, and geostatistical analyses will be conducted. Details of data monitoring and assessment are provided in section B.4.

Pre- and post-IFDM salinity levels (variability, distribution) will be compared, analyzed, and used for crop rotation and drainage management recommendations to growers. Effectiveness of IFDM practices and reduction of AF/ac from Quantifiable Objective 106 will be assessed for each farm. All the findings will be detailed in yearly progress reports and in the final report.

C. Outreach, Community Involvement, and Information Transfer

1. Outreach efforts

The project will be conducted in partnership with DWR, RCD, WWD, and growers faced with the problem of salinization, reduced crop yields, and overall degradation of the quality of their farmlands. The study will directly benefit growers who will be interested in implementing IFDM practices by providing both an initial baseline of soil salinity levels on their farmlands as well as a decision-making tool for drainage system management and crop rotation selection with annual salinity measurements.

2. Training, employment, and capacity building potential

Up to 20 growers and their staff, as well as several DWR/RCD/WWD managers and program coordinators will participate in this project. Concepts of soil salinity and use of EM sensor will be explained during workshops and seminars. We will also educate growers about soil salinity monitoring and irrigation drainage management and application. Training programs on soil salinity assessment will be offered at venues such as CIT, Fresno State, and/or other education centers.

3. Dissemination of the results

Target audiences: The results will be transferred to farmers, DWR/RCD/WWD managers and program coordinators, public, cooperators, scientists, etc.

Meetings-seminars-showcases: Results will be presented using maps, posters, and slides during seminars, farmer/community meetings, workshops, as well as statewide, regional, and national meetings and conferences, such as the annual ASA (California chapter) Plant and Soil Conferences and the ASA-CSSA-SSSA meetings.

Reports and publications: Annual progress report will be provided as well as a final report detailing the three-year results. Research findings will also be published in the "Update" newsletters, brochures, agricultural bulletins, and refereed journals.

4. Copy of letters

Copies of the letters sent to Mr. Jose Faria from the California Department of Water Resources, Mr. Red Martin of the Westside Resource Conservation District, and Mr. Jerry Robb from the Westlands Water District, are attached with this proposal.

D. Qualifications of the Applicants, Cooperators, and Establishment of Partnerships

1. Resume of principal and co-investigators for the project

See enclosed resumes of Florence Cassel Sharmasarkar, Dave Goorahoo, David Zoldoske, and Peter Canessa.

2. Role of external cooperators

Michael Spiess, General Manager at The Agricultural Technology Information Network (ATI-NET) will be responsible for coordinating the work relating to Objective 2 and providing CIT with the georeferenced digital map data and computerized attribute data.

3. Partnerships

The project will be conducted in partnership with the California Department of Water Resources, Westside Resource Conservation District, and Westlands Water District (see attached letters in section C.4). DWR has extensive experience in IFDM program design and implementation.

E. Costs and Benefits

1. Budget summary and breakdown

The study will be conducted over a three-year period from July 1, 2001 to June 14, 2004

Items	Year 1	Year 2	Year 3	Total	Total
	Funds Requested				Matching Funds
A. Salaries and Wages	15,000	15,000	15,000	45,000	5,000
B. Fringe Benefits	4,200	4,200	4,200	12,600	1,400
C. Supplies	2,500	2,500	2,500	7,500	
D. Equipment	22,000				100,000
E. Services or Consultants	10,000	10,000	10,000	30,000	
F. Travel	3,000	3,000	3,000	9,000	
G. Other direct Costs	11,000	11,000	11,000	33,000	
H. Total Estimated Costs	67,700	45,700	45,700	159,100	
+ 10% indirect costs	6,770	4,570	4,570	15,910	
TOTAL COSTS	**74,470**	**50,270**	**50,270**	**175,010**	**106,400**

2. Budget justification

The overall funding request is $175,010, which will be divided over the three years of the project. A higher provision has been made for the first year ($76,670) to acquire the EM equipment and data analysis softwares. The total matching funds are $106,400. The details of the expenditures are presented below.

A. Salaries and Wages

(1) A technician will be employed part-time (50%) at $15,000 per year for three years to collect the EM measurements.

(2) Matching funds include time contribution from Dr. Zoldoske at $5,000 for three years.

B. Fringe Benefits

A 28% benefit is added to all salaries described above.

C. Supplies

Provision is made for $1,000 per year for supplies needed to assemble the MSCA system, $500 for laboratory chemicals and disposables, and $1,000 for office supplies and preparation of reports/presentations (slides, posters, maps, photographs, fliers, brochures) and manuscripts, over three years.

D. Equipment

Funds are requested the first year to purchase the following items:
(1) a DDEM-38 sensor to collect the EC data at $19,000.
(2) two computer softwares for generating maps and conducting statistical analyses at $1,000.
(3) miscellaneous equipment for data collection and analysis at $2,000.

Matching funds of $100,000 for the three years include ATVehicle, GPS receiver, computers, Sandia/ESAP-95/GIS-ARCview softwares, and trailer.

E. Services and consultants

Michael Spiess, General Manager at The Agricultural Technology Information Network (ATI-NET), will be employed at $5,000 per year for three years to conduct Objective 2.

F. Travel

(1) Provision of $2,300 per year for three years for driving the MSCA system from Fresno to the farms in sub-region 10 and collecting *in-situ* EM data.
(2) Costs of $700 per year for domestic travel and presentations of findings to the growers, cooperators, DWR engineers, and researchers during meetings/workshops/seminars/conferences.

G. Other direct costs

(1) Funds requested at $10,000 per year for three years for planning and designing the research, analyzing data, and providing recommendations.
(2) Maintenance of the ATV/DDEM-38 sensor system was evaluated at $1,000 per year.

H. Total Costs

Indirect costs are charged at 10% of Total Estimated Costs.

3. Non-quantified outcomes expected to directly or indirectly benefit the CALFED program

The proposed research is expected to evaluate the effectiveness of IFDM practices on reducing soil salinity. Repeated surveys will provide the rate of salinity increase or reclamation on the farms. Measurements at various depths will reveal the presence of uniform, regular or inverted (i.e., EC decreases with depth) salinity profiles in the fields. The study will also lead to crop rotation and drainage management recommendations.

The project is expected to increase the operating efficiency of the IFDM system. Site assessment and ongoing monitoring of the salinity within the management areas are important to maintaining the productivity of the cropping area. Monitoring trends can facilitate changes in management strategies to optimize the operational efficiency of the system.

The proposal site assessment and ongoing monitoring of field salinity will improve the reliability of the system by providing critical management information. Good information should lead to better operational decisions and help ensure the long-term viability of the project. This helps protect the substantial investment put forth by the grower and others. Stability of this farming practice should improve the grower’s ability to forecast economic returns. This intern will provide a more stable base to the local community. High, on farm use efficiency reduces the growers need to seek additional water supplies.

Upwards of ninety percent of the water potentially lost to deep saline sinks can be utilized by the IFDM system. CIT is proposing to assess and monitor approximately 20,000 acres (20 farms of 1000 acres each) with an estimated aggregate annual savings of 3,500 and 4,000 acre-feet of water. Over the three-year life of the project the successful implementation of the IFDM systems could realize 10,000 to 12,000 acre-feet of water savings.

The overall research will be agronomically and environmentally beneficial for the growers implementing IFDM practices and will help the cooperators/scientists assess and understand the effects of IFDM practices on soil salinity. The study will also aid in decision making for future salinity-reclamation programs.

4. Assessment of Costs and Benefits

Item	**Amount**	**Units**	**Beneficiary**
Non-Quantified Benefits			
Improved information for IFDM system design and operation			Growers in Sub-regions 10 and 14
Reduction from Quantifiable Objective	3,500 - 4,000	AF/year	CALFED Quantifiable Objective 106

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